

# DREDGED MATERIAL RESEARCH PROGRAM



TECHNICAL REPORT D-78-II

## HABITAT DEVELOPMENT FIELD INVESTIGATIONS, RENNIE ISLAND MARSH DEVELOPMENT SITE GRAYS HARBOR, WASHINGTON SUMMARY REPORT

by

Mary K. Vincent

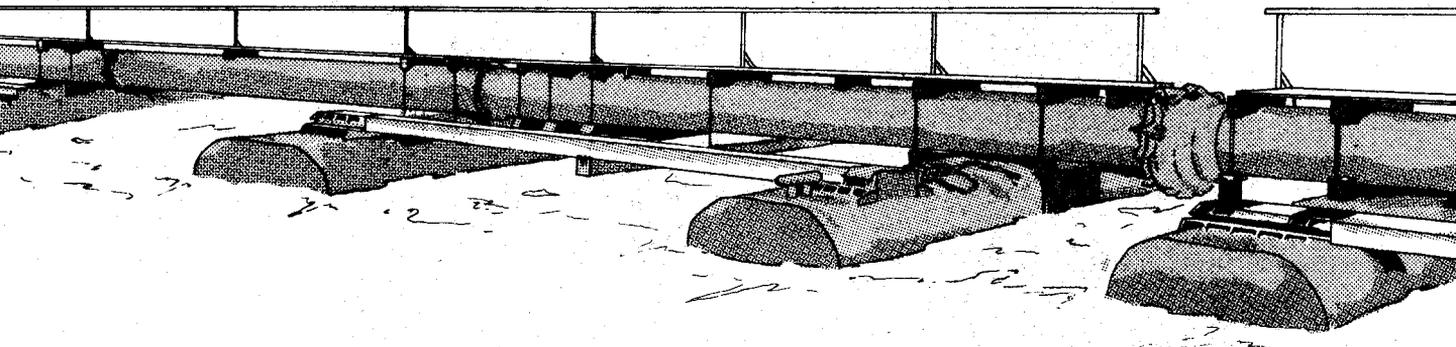
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April 1978

Final Report

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Prepared for Office, Chief of Engineers, U. S. Army  
Washington, D. C. 20314

Under DMRP Work Unit No. 4A14D

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IN REPLY REFER TO: WESYV

15 June 1978

SUBJECT: Transmittal of Technical Report D-78-11

TO: All Report Recipients

1. The technical report transmitted herewith represents the results of one of a series of research efforts (Work Units) conducted as part of Task 4A (Marsh Development) of the Corps of Engineers' Dredged Material Research Program. Task 4A was part of the Habitat Development Project (HDP) and had as its objective the development and testing of the environmental and economic feasibility of using dredged material as a substrate for marsh development.
2. Marsh development on dredged material was investigated by the HDP under both field and laboratory conditions. The study reported herein (Work Unit 4A14D) is an evaluative summary of marsh development investigations near Rennie Island in Grays Harbor, Washington. This project was terminated after baseline studies indicated that high wave energies at the site would make marsh establishment infeasible without a substantial protective structure. Subsequent foundation analyses indicated a weak unstable condition that made a conventional earthen or rock structure unsuitable. An evaluation of various alternative structures revealed that no economically feasible options were available, and the project was terminated. This evaluative project summary contains all pertinent information generated in Work Units 4A14A-C.
3. A total of nine marsh development sites were selected and designed at various locations throughout the United States. Six sites were subsequently constructed in the following areas: Windmill Point on the James River, Virginia (4A11); Buttermilk Sound on the Intracoastal Waterway in Georgia (4A12); Apalachicola Bay, Apalachicola, Florida (4A19); Bolivar Peninsula, Galveston Bay, Texas (4A13); Pond No. 3, San Francisco Bay, California (4A18); and Miller Sands Island, Columbia River, Oregon (4B05). Detailed design for marsh restoration at Dyke Marsh on the Potomac River (4A17) has been completed, but project construction is awaiting additional interagency coordination. Marsh development at Branford Harbor, Connecticut (4A10) was terminated because of local opposition to that project.

WESYV

15 June 1978

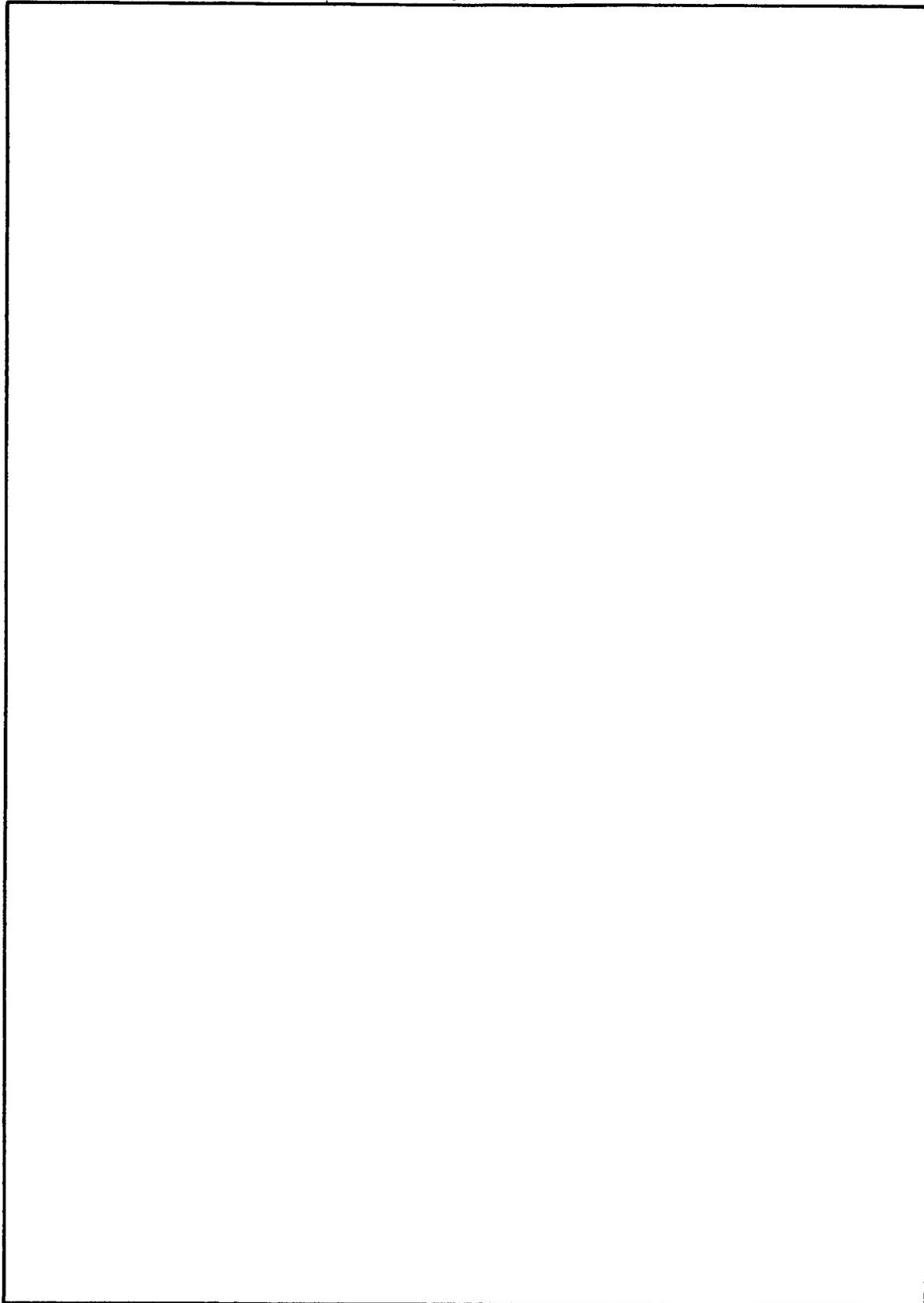
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4. Evaluated together, the field site studies, plus ancillary field and laboratory evaluations conducted in Task 4A, establish and define the range of conditions under which habitat development is feasible. Data presented in the research reports conducted in this task will be synthesized in the technical reports entitled "Upland and Wetland Habitat Development with Dredged Material: Ecological Considerations" (2A08) and "Wetland Habitat Development with Dredged Material: Engineering and Plant Propagation" (4A22).



JOHN L. CANNON  
Colonel, Corps of Engineers  
Commander and Director

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A salt marsh development project originally planned for Rennie Island in Grays Harbor, Washington, was terminated after a detailed baseline analysis. These studies indicated that extremely high wave energy conditions at the site would make marsh development infeasible without a substantial protective and retaining structure. Foundation analyses indicated a weak, unstable condition that made a conventional rock or earthen dike unsuitable. An evaluation of various alternative structures revealed that no economically feasible options were available, so the marsh development project was terminated.		



## PREFACE

This report presents the summary of activities that occurred during the habitat development field study at Rennie Island in Grays Harbor at Aberdeen, Washington. The objective of the study was to develop a marsh on a dredged material substrate; however, early in the site assessment phase the project was determined to be infeasible and so was terminated.

The investigation was conducted as part of the Corps of Engineers Dredged Material Research Program (DMRP) under Task 4A, "Marsh Development," of the Habitat Development Project (HDP). The DMRP is sponsored by the Office, Chief of Engineers (DAEN-CWO-M), and is being managed by the Environmental Laboratory (EL) of the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi.

The Seattle District conducted an engineering survey and developed plans and alternate plans for dike design and construction under Inter-agency Agreements No. WESRF 75-26 and 75-131. The major Seattle District personnel involved included: Drs. S. F. Dice and F. Weinman and Mr. L. Juhnke.

Coastal Ecosystems Management, Inc., of Ft. Worth, Texas, with Dr. R. Parker as the principal investigator, prepared preliminary work statements for the Rennie Island site under Contract No. DACW39-75-M-2124. The Fisheries Research Institute (FRI) of the University of Washington, Seattle, completed a literature review of the Grays Harbor estuary and developed baseline sampling plans to inventory and assess environmental parameters at Rennie Island under Contract No. DACW67-75-C-0086. Principal investigators for the FRI study were Drs. E. O. Salo and Q. J. Stober. Others at FRI who had responsibilities for various aspects of the project were Dr. A. W. Erickson and Messrs. S. P. Felton, M. A. Kyte, A. D. Every, E. E. Hansen, M. S. Meyers, and B. K. Firth.

Several persons at EL administered and monitored the project. The study was under the general supervision of Dr. J. Harrison, Chief, Dr. R. T. Saucier, Special Assistant for the DMRP, Dr. C. J. Kirby, Chief, Environmental Resources Division, and Dr. H. K. Smith, Manager

of the HDP. Site manager for the Rennie Island study was Dr. J. E. Bryne. The report was compiled at EL by Ms. M. K. Vincent. The section in the text on engineering investigations and Appendix D on engineering considerations were written by Mr. R. L. Montgomery, EL.

The Commanders and Directors of WES during the period of contract study, report preparation, and summary report compilation were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director of WES was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)  
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.4	millimetres
feet	0,3048	metres
miles (U. S. statute)	1.609344	kilometres
miles (U. S. nautical)	1.852	kilometres
acres	4046,856	square metres
square miles (U. S. statute)	2.589988	square kilometres
cubic yards	0.7645549	cubic metres
feet per second	0,3048	metres per second
miles (U. S. statute) per hour	1.609344	kilometres per hour
cubic feet per second	0.02831685	cubic metres per second
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
tons (force) per square foot	95.76052	kilopascals
degrees (angular)	0.01745329	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*

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\* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula:  $C = (5/9)(F - 32)$ . To obtain Kelvin (K) readings, use:  $K = (5/9)(F - 32) + 273.15$ .

HABITAT DEVELOPMENT FIELD INVESTIGATIONS, RENNIE ISLAND

MARSH DEVELOPMENT SITE, GRAYS HARBOR, WASHINGTON

SUMMARY REPORT

PART I: INTRODUCTION

Background

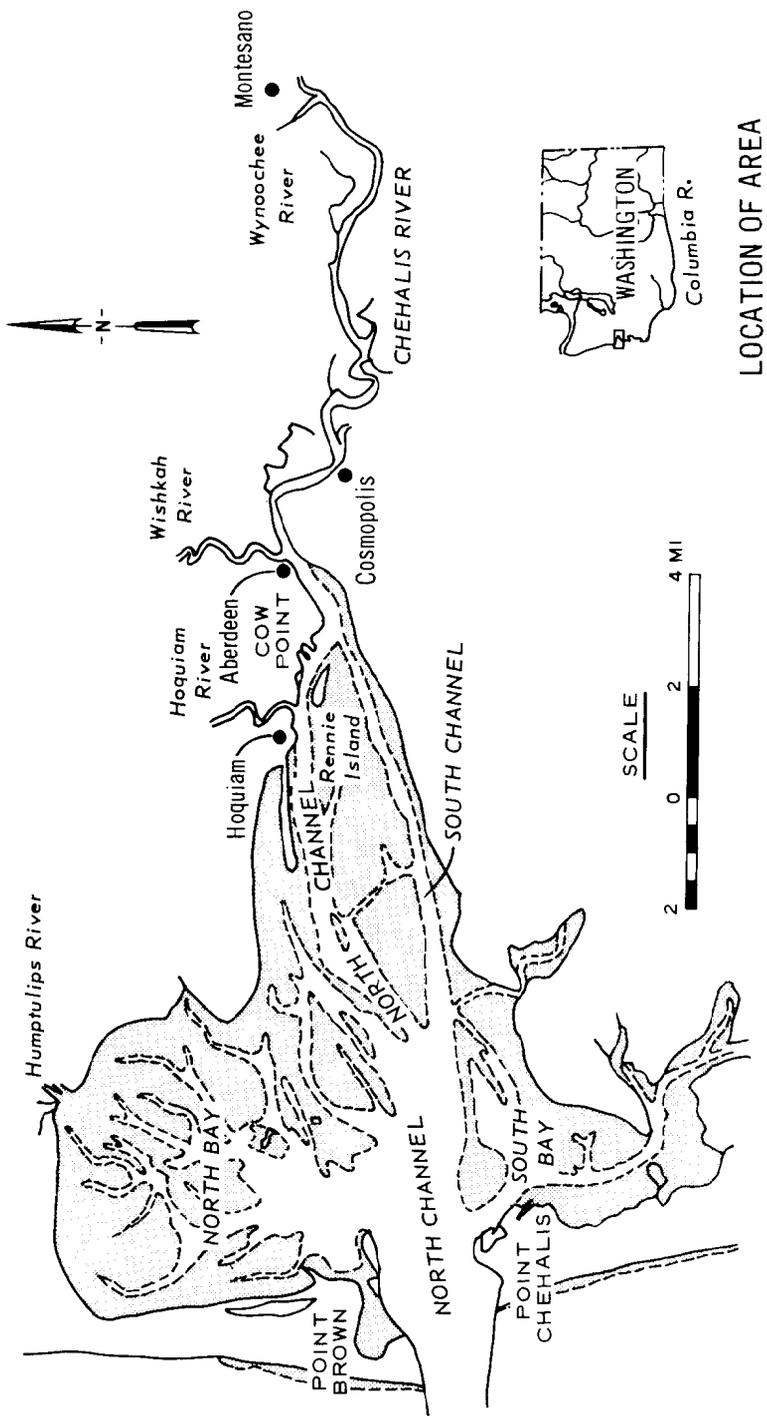
1. The Environmental Laboratory (EL) of the U. S. Army Engineer Waterways Experiment Station is conducting a comprehensive Dredged Material Research Program (DMRP) for the Office, Chief of Engineers. Objectives of the DMRP are to provide more definitive information on the environmental aspects of dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible disposal alternatives, including consideration of dredged material as a manageable resource.

2. The Habitat Development Project (HDP), one aspect of the DMRP, is an interdisciplinary research effort aimed at developing marsh and upland habitat using dredged material as a substrate. Objectives of the study are to: determine what mechanisms exist or evolve that cause the success or failure of habitat development; determine the environmental effects of dredged material disposal and habitat development; and develop feasible alternatives for disposal of dredged material that will improve the biological characteristics of the disposal site.

3. A major part of the research in habitat development is being undertaken through a field program with study sites located in different coastal environments. These planned development efforts were designed to assess the potential use of dredged material as a habitat substrate and provide field-tested alternatives to conventional methods of dredged material disposal.

Purpose and Plan of Study

4. The Rennie Island field site, located in Grays Harbor near Aberdeen, Washington (Figure 1), was designed to field test marsh



LOCATION OF AREA

Figure 1. Locational points in Grays Harbor

development with fine-grained dredged material in a marine environment. The site also offered the opportunity to evaluate marsh development in a high-energy, high-tidal-range environment. Marsh development was planned in association with an authorized maintenance dredging project in Grays Harbor.

5. Data collection and assessment were to be conducted before, during, and after disposal operations, and to be thoroughly coordinated with all concerned local, State, and Federal government agencies and private organizations. The study was to proceed through five phases: a baseline data inventory phase; an operational phase, including dike design and construction and dredged material disposal; a pre-propagation monitoring phase; a site preparation and propagation phase; and a two to three-year post-propagation monitoring phase.\* Physical and chemical parameters were to be monitored throughout to detect changes in the dredged material that might affect vegetation establishment and management and consequent animal use patterns.

#### Approach and Scope

6. The approach to habitat development using dredged material is based on the hypothesis that alternative disposal techniques can be designed that will improve the biological characteristics of the disposal site and the adjacent area. The approach recognizes that short-term degradation of certain biological communities can occur, but foresees that short-term losses can be more than compensated for by long-term biological gains. For example, successful site development can result in increased energy and material transfer to all trophic levels and a general increase in carrying capacity and community stability.

7. The scope of the initial research, prior to actual marsh development, was directed toward three main efforts: (a) review of pertinent literature and data concerning the physical, chemical, and biological conditions of the site and general area (DMRP Work Unit

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\* The study was terminated during the first phase. The termination factors are discussed in Part IV: Site Assessment.

4A14C); (b) development and implementation of a sampling plan to provide physical, biological, and chemical assessment of the site (DMRP Work Unit 4A14B); and (c) coordination with local, State, and Federal agencies in a survey of the site (DMRP Work Unit 4A14A). These efforts were to focus on the documentation of spatial and temporal environmental variability and to determine the feasibility of marsh development at the Rennie Island site.

### Overview and Termination

8. After several months study in the Grays Harbor area, Rennie Island was identified in the fall of 1974 as a potentially favorable site where 10 to 15 acres\* of salt marsh development could be attempted. The Seattle District undertook a series of engineering studies to determine foundation conditions at the site and to develop a suitable dike design to retain and protect dredged material in tidal variations up to 14 feet. A contract was let to the Fisheries Research Institute of the University of Washington to inventory and assess existing environmental conditions at Rennie Island.

9. Engineering studies indicated that Rennie Island had extremely weak foundation conditions. The dike design then, already complicated by high energy and high tidal range, would also need to accommodate an unstable foundation. Several conventional and nonconventional structures were considered and various combinations and sizes were analyzed. However, in view of availability of construction materials it was concluded that construction of the type of structures required for the site would be unrealistic and prohibitively expensive.

10. In late spring of 1975, the Rennie Island site development planning was terminated. The Fisheries Research Institute terminated its baseline survey after completing the pilot study and sampling design phases of their work.

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\* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 5.

## Report Structure

11. This report provides a summary of the work performed on the Rennie Island marsh development project. Part II discusses the criteria and justification for the selection of the site. Part III provides a description of the general area and the site. Site assessment and the reasons for project termination are detailed in Part IV. In the final section, Part V, certain aspects of this study that have application to similar projects are discussed.

12. The appendices contain further information on the general area and the site and detail the findings of the work units. Appendix A gives an annotated bibliography, part of which was prepared during the study on work unit 4A14C (conducted by the Fisheries Research Institute). Appendices B and C are also products of Work Unit 4A14C. Appendix B lists plants and animals that have been observed in the Grays Harbor area and on Rennie Island. Appendix C describes the tentative sampling and work plan. Appendix D, based on data and information provided by the Seattle District for Work Unit 4A14A, discusses the engineering considerations at Rennie Island.

## PART II: SITE SELECTION

### Site Selection Criteria

13. In order to address adequately the national problem of developing alternatives for dredged material use, the HDP has selected upland and marsh field study sites in a variety of environments. The selection of each site was based on seven general criteria:

- a. The research sites should give good regional representation. These regions were North Atlantic, South Atlantic, Gulf of Mexico, Pacific Coast, and Great Lakes.
- b. The research sites should provide representations of freshwater, brackish water, and saltwater habitats with associated community types.
- c. The research sites should provide representation of sand, silt, and clay dredged material substrate types, and of clean versus contaminated sediments.
- d. The research sites should not be located in extreme energy systems. For example, a New England or Pacific Coast rocky shoreline would be inappropriate for marsh habitat development.
- e. The research sites should be compatible with ongoing operations and maintenance dredging being performed in CE Districts and should be representative of projects within CE Districts.
- f. Logistical support should be available at each site.
- g. The dredging project associated with each site development should be compatible with the time frame of the DMRP.

### Justification for Rennie Island

14. Based on evaluation of the seven general site selection criteria, the justifications for conducting a marsh development study on Rennie Island were:

- a. The proposed site is representative of the coastal Pacific Northwest, having a climate characterized by cool, dry summers and stormy, wet winters and having an unequal semidiurnal tidal regime.

- b. The proposed site is populated by representative brackish water flora and fauna of the area. Salinity ranges from about 0 ppt to 25 ppt depending on season, river discharge, wind direction, and other environmental factors.
- c. The proposed substrate is classified as silty sand or sandy silt. There may be some contamination by sulfite liquors associated with an adjacent paper mill waste lagoon.
- d. The proposed site is located in a ~~high-tidal-energy~~ regime, but one that does support a natural marsh community. A large expansive marsh could probably not be established under these conditions, but development of a small marsh fringe behind a protective engineering structure would be feasible.
- e. The project would be conducted with complete cooperation from the Seattle District and would use dredged material from normal maintenance dredging of a navigation channel.
- f. There are qualified potential contractors in the area with relevant expertise and experience.
- g. The local dredging schedule is compatible with the DMRP's time frame.
- h. The proposed study area has no title or property use restrictions. (One other site was initially considered but use of the property was not granted by its owner.)

#### General Discussion of Other HDP Sites

15. During the course of the HDP a total of 11 sites were selected for field studies and demonstration projects (Figure 2). One other site besides Rennie Island was terminated. This was the marsh development site at Branford Harbor, Connecticut.

16. Two sites were selected in the Pacific Northwest region: Rennie Island, Washington, and Miller Sands, Oregon. Miller Sands, near Astoria, Oregon, and in the Columbia River was selected for both marsh and upland habitat development in a sandy, predominately freshwater, tidal environment.

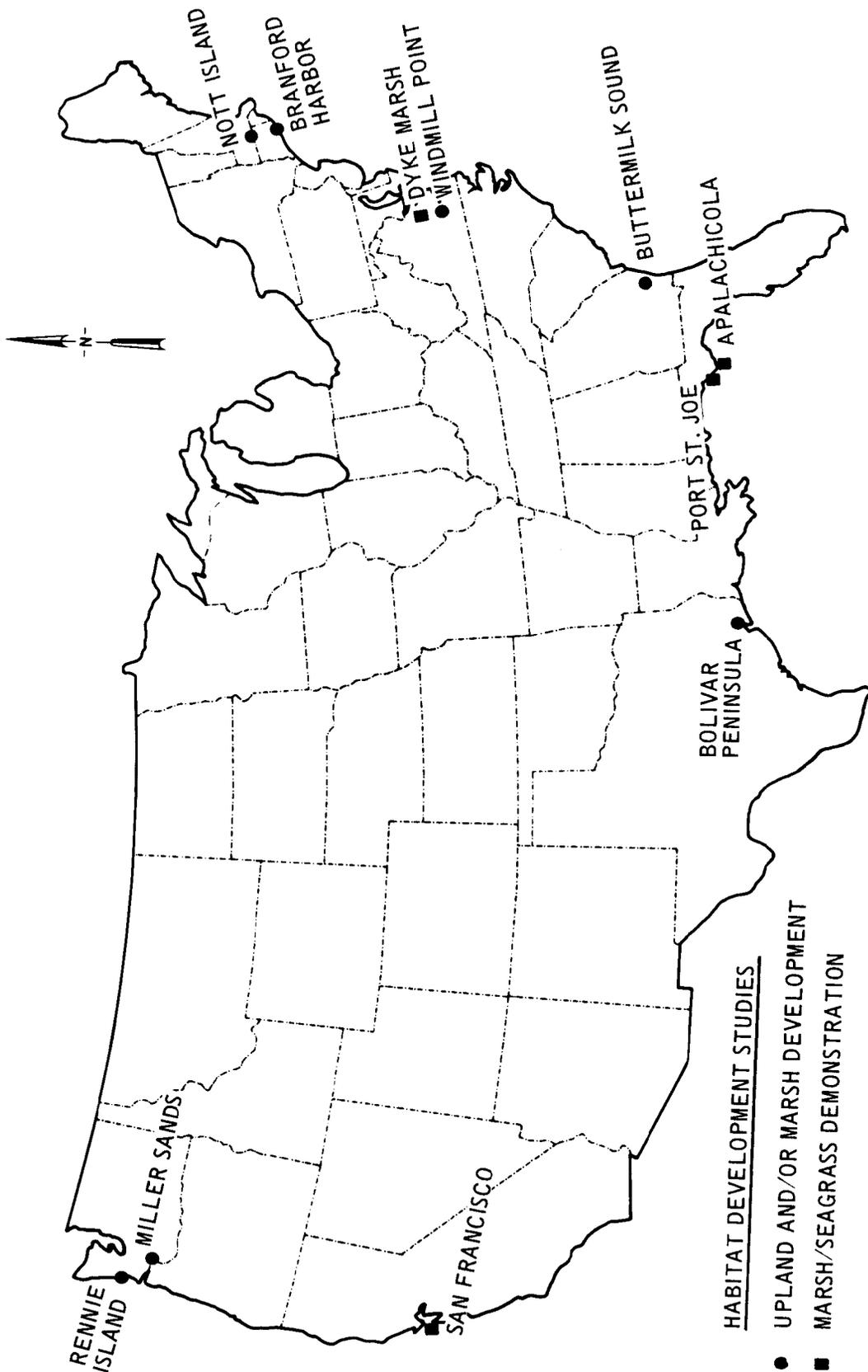


Figure 2. Sites selected for field studies and demonstration projects within the Habitat Development Project

## PART III: SITE DESCRIPTION

### Environmental Setting

17. Grays Harbor forms part of an estuarine complex that includes several rivers, principally the Chehalis, Wishkah, and Hoquiam, that drain the surrounding mountains in southwest Washington. From its 2.5-mile-wide jetty-bracketed entrance to the Pacific Ocean, the harbor stretches 15 miles eastward to its head at the Chehalis River at Aberdeen. Roughly pear-shaped, the harbor attains a maximum width of 13 miles near its Pacific outlet (Figure 3).

18. The wooded surrounding uplands are less than 2500 feet in elevation and are underlain by varying rock types including soft Pleistocene silt, sand, and gravel as well as harder sedimentary and volcanic rocks of the Tertiary period. The environmental setting is the basis for the major economic activities, which include forestry and fishery industries, a related shipping trade, and tourism.

### Climatological characteristics

19. The climate of the Grays Harbor area is typified by mild summers and cool wet winters (Donaldson and Phillips, 1972). Temperatures are moderate and average 50<sup>o</sup>F over the year. Winter temperatures seldom fall below 25<sup>o</sup>F and average 42.7<sup>o</sup>F (January ranges 34<sup>o</sup> to 45<sup>o</sup>F) while summer temperatures average 56.8<sup>o</sup>F and rarely exceed 85<sup>o</sup>F (July ranges 50<sup>o</sup> to 70<sup>o</sup>F). The area normally has heavy annual rainfall varying from 70 to 90 inches per year. Areas of the nearby Willapa Hills receive over 100 inches annually. Most of the precipitation, about 75 percent, occurs from September to May. Average annual snowfall is 8.9 inches and average length of growing season is 180 days. Prevailing southwest winds blow on shore, frequently exceeding 40 mph, and provide the moist maritime climate typical of the Pacific Northwest region.

### Hydrological characteristics

20. The general characteristics of the Grays Harbor estuary are the semidiurnal unequal tides typical of the Pacific Coast, large

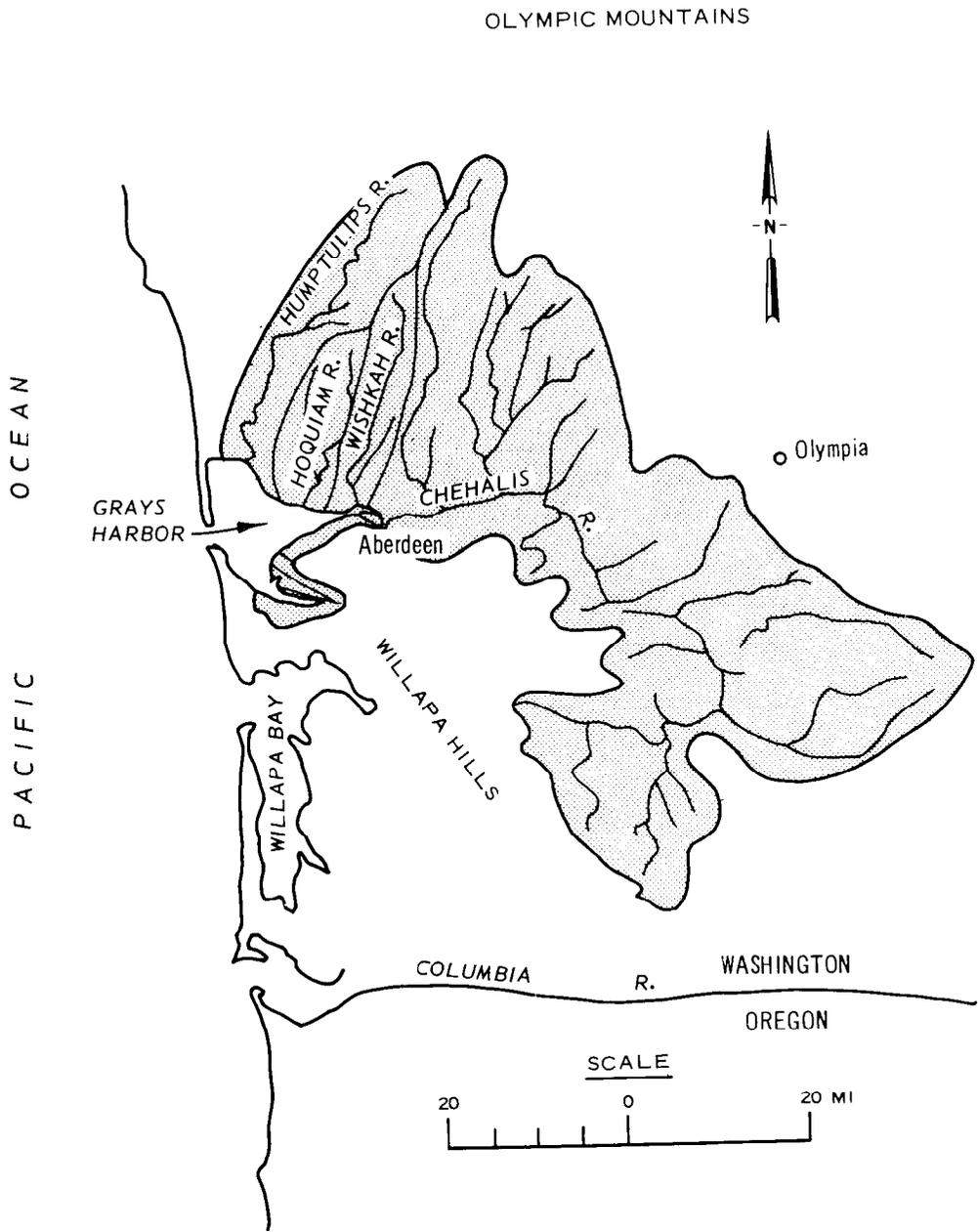


Figure 3. Environmental setting, Grays Harbor

expansive tidal flats particularly in the north and south bays (Figure 1), and low to medium salinity (from about 28 ppt inside the harbor entrance to about 14 ppt at the confluence of the Wishkah and Chehalis Rivers). The estuary provides a deepwater port with a 30-ft minimum depth in the ship channel and a maximum harbor depth of 60 ft. The main part of the channel, from the entrance to Cow Point (Figure 1), is maintained at a 350-ft width.

21. Tides. Along the Washington coast a higher and lower high tide as well as a higher and lower low tide occur each lunar day. The mean tide range within the harbor is 7.8 ft. At Aberdeen, Washington, the mean high water is 9.2 ft and mean low water is 1.4 ft with a mean lower low water elevation of 0.0 (Beverage and Swecker, 1969).

22. At mean higher high water, the water surface of the entire estuary is approximately 94 square miles. At mean lower low water, the surface area is reduced to 35 square miles, so providing about 59 square miles (nearly 38,000 acres) of intertidal lands (U. S. Army Corps of Engineers, Seattle District, undated). Much of the tidal flat area is about 1 to 2 feet above mean lower low water and is important in the movement, mixing, and reaeration of harbor waters during tidal ebb and flood.

23. Tides move slowly up the estuary; high tide occurs 29 minutes later at Aberdeen than at the harbor mouth. Maximum mean velocities in the upper harbor vary from about 3 fps during floodtide to about 4.5 fps during ebbtide.

24. Watershed and salinity. The Grays Harbor watershed covers some 2,500 square miles; the Chehalis River and tributaries drain about 80 percent of that area. Four river systems provide a mean daily freshwater inflow of 10,600 cfs, with about 90 percent being delivered by the Chehalis (Beverage and Swecker, 1969).

25. Since fresh water contributes significantly to the estuary, Grays Harbor is said to be a "positive" estuary, yet there is no distinct saltwater wedge. The salinity gradient from the mouth to the head of the harbor is fairly uniform and varies predictably and seasonally. During summer, after extended periods of low freshwater flow,

the harbor waters are well-mixed; vertical stratification accompanies high flow during the summer. Near Aberdeen, salinity varies from 0.0 ppt at lower low water (llw) to about 10.0 to 12.0 ppt at higher high water (hhw). Saltwater extends at least 28.4 nautical miles from the harbor mouth, as far as Montesano, Washington (Figure 1).

26. Water quality. Water quality in the Grays Harbor estuary has been a major problem for over 40 years; the first comprehensive investigation of water quality was conducted by the Washington State Water Pollution Control Commission in the late 1930's. According to Eriksen and Townsend (1940), dissolved oxygen was depressed by sulfite waste liquors and low oxygen and pulpmill pollutants were often responsible for fish mortality. Studies since 1940 have restated the problem. For the period 1962 to 1966, Deschamps (1968) documented one fish kill, observations of distressed fish, low oxygen levels occurring over prolonged periods, and a reversal of the upstream migration pattern of adult salmon. Westley (1967) reported an inhibition of phytoplankton photosynthesis in upper Grays Harbor that he attributed to turbidity, sulfite waste liquor, and some undetermined factor. Deschamps and Phinney (1971) found extensive fish mortalities in upper Grays Harbor, often at dissolved oxygen levels higher than the 4.5 mg/litre Washington State minimum standards.

27. Forest industries and dredging have had the major impact on water quality (U. S. Army Engineer District, Seattle, undated). Logging practices in the watershed have created conditions leading to increased runoff of precipitation, increased volume of surface water, and lower, warmer tributary inflow during the low-flow months. Maintenance dredging has resulted in increased turbidity, lowered dissolved oxygen, and increased nutrient levels.

28. Dredging impacts are highly variable and have both short- and long-term effects that are generally limited to the immediate area. Short-term impacts may include lowered water quality due to the resuspension of sediments and the release of toxic and oxygen demanding chemicals such as ammonia, hydrogen sulfide, nitrate, and phosphorus. Long-term effects include changes in the particle size and chemical

composition of habitat substrates that may impact on the diversity and abundance of benthic organisms.

29. Pulp and paper mill effluent, particularly sulfite waste liquor, is the major pollutant in the harbor, and at least in the past, has significantly increased the biochemical oxygen demand (BOD) (Beverage and Swecker, 1969). In recent years, numerous public and private organizations have come to recognize that a major water problem exists and have been attempting to improve the situation by relocating effluent outfalls and limiting discharge to ebbing tide (Beverage and Swecker, 1969; U. S. Army Engineer District, Seattle, undated).

#### Sedimentological characteristics

30. The general depositional pattern within Grays Harbor is typical of estuaries; marine deposition dominates the mouth area, riverine the head, and mixed in between. From Aberdeen to the harbor mouth, bottom materials are mostly sand and silty sand. The composition of the material dredged from navigation channels is approximately 50 percent sand and 6 percent organic content.

31. Also like most estuaries, Grays Harbor is continually being filled in with riverborne silts and sands and alongshore littoral drift material. Logging practices and poor land management have increased river sediment loads and, in turn, harbor deposition.

32. Most of the movement of material in the harbor is by tidal ebb currents and dredging. Studies by the U. S. Army Engineer District, Seattle, show that ebb currents predominate near the bottom in the entrance and outer portions of the harbor. Currents here cause the bulk of dredged material disposed in the mouth area to be transported out of the estuary.

#### Ecological Setting

33. Grays Harbor contains at least 50 miles of shoreline, including the margins of estuarine islands and sand spits, and nearly 38,000 acres of intertidal areas. Both shoreline and tidal area environments provide habitat for a diversity of plant and animal organisms (Appendix

B). No endangered species are known to exist in the area.

#### Common habitats

34. Based on observations and data collected during a study of biota of Grays Harbor, Wolfe and Moore (1974) attempted to define habitats as delineated by biological and physical properties. The six habitats they list are not sharply defined, but grade into one another: adjacent floodplain, marshland, mudflat, sand flat, eelgrass flat, and subtidal. They did not include the man-made jetty habitat that supports a distinct, though small rocky coast marine community.

- a. The adjacent floodplain habitat, surrounding the estuary, extends from the mean high high water level to the wooded foothills. This habitat also includes most of the municipal areas of Grays Harbor.
- b. The marshland habitat, existing mainly in the north and south bays and along the south channel (Figure 1) is characterized by aquatic vegetation and is flooded by runoff and high tides. Salt marsh vegetation, including various grasses and rushes, and periodically submerged plants like pickleweed (*Salicornia*) provide nutrition and shelter for various plankton, invertebrates, fish, and waterfowl. The marshlands contribute nutrients, primarily through detritus, to the estuary.
- c. The mudflat habitat, occurring between the high tidal and low tidal zones, is the largest and most diverse habitat in Grays Harbor. Mudflat sediments are characteristically clay and silt. The most common organisms here are burrowing invertebrates (snails, worms, and shrimp-like crustaceans), juvenile fish, and wading birds.
- d. The sand flat habitat occurs in the low intertidal areas of the western third of the estuary. The sand substrate supports populations of polychaetes, shrimp, and clams.
- e. The eelgrass flats are more clearly defined as a specialized habitat type within low intertidal or wholly subtidal areas than as a separate habitat type. The eelgrass flats are characterized by the abundance of eelgrass (*Zostera marina*) and dwarf eelgrass (*Zostera nana*). The eelgrass provides nutrition and shelter for juvenile fish and invertebrates (including the Dungeness crab, *Cancer magister*, the most important commercial crustacean in the estuary).
- f. The subtidal habitat consists of those areas not exposed during lowest low tide. The primary organisms are fish and invertebrates.

35. Besides providing shelter and forage for many organisms, the intertidal areas are extremely important to the biological productivity of Grays Harbor. These areas are the sites for much of the primary productivity of marine plants and are essential to the recycling of nutrients in the harbor. The detritus produced by plants associated with the intertidal areas is consumed by great numbers of tiny animals that form a large and necessary portion of the marine food chain.

36. About one third of all bird species occurring in Washington can be observed in the Grays Harbor area (U. S. Army Corps of Engineers, Seattle District, undated). Besides lying in the Pacific flyway, Grays Harbor provides particularly useful and attractive habitat for shore birds and migratory birds by way of its extensive intertidal areas. Migration into the area begins in August and peaks in October or November.

#### Economic aspects

37. Economically important groups of organisms found in Grays Harbor include fish and shellfish. All the tributary rivers contribute to the anadromous fish runs. The Humptulips River accounts for approximately one third of the harbor's salmon run, which consists of chum (*Oncorhynchus keta*), Chinook (*O. tshawytscha*), and Coho salmon (*O. kisutch*), as well as steelhead (*Salmo gairdneri*) and cutthroat trout (*S. clarki*). Over 20 million small downstream migrants enter Grays Harbor from February through June (U. S. Army Corps of Engineers, Seattle District, undated).

38. Nine species of clams are found in Grays Harbor (Smith and Herrman, 1972). Several areas in North and South Bay appear to have the potential for propagation and growth of the Pacific oyster (*Ostrea gigas*). Sandflats, mudflats, and eelgrass beds are the principal rearing areas for small Dungeness crabs, which later migrate to deeper water near the lower harbor. Populations of burrowing shrimp (*Callinassa californiensis*) are located in the inner bays of the harbor, while free swimming shrimp (*Pandalus jordani*) move out to deeper waters offshore.

39. The well-developed fisheries industry is largely based in the

ocean waters where crab, shrimp, tuna, etc., are harvested. Within the harbor salmon, crab, oysters, sole, cod, halibut, and shrimp provide a good annual source of revenue.

### Operational Setting

40. Grays Harbor lies within the operational jurisdiction of the Seattle District of the U. S. Army Corps of Engineers. The first dredging operation took place in 1916 (in conjunction with the Grays Harbor and Bar Entrance Project) when the bar near the channel entrance was dredged to keep the harbor open. Maintenance dredging is now done annually in the primary navigation channel between the harbor entrance and the three major port cities of Hoquiam, Aberdeen, and Cosmopolis (Figure 1). The primary channel is about 23 miles long. The channel is authorized to be maintained at 30 feet deep at mllw and from 200 to 600 feet wide (350 feet wide for the 14-mile distance from the harbor entrance to Aberdeen and 600 feet at the harbor entrance).

41. The eastern half of Grays Harbor is maintained by pipeline dredge and the west by hopper dredge. Hydraulic dredging takes place only during the winter and spring months, October to May, due to restrictions imposed to protect the salmon fishery.

42. Approximately 1.8 to 2.0 million cu yds of material are dredged each year and disposed at deepwater sites near the harbor entrance or in areas adjacent to the channel including diked uplands and tidelands. One such disposal area, supplemented with fill, is now the airport of Hoquiam (Moon Island Airport).

### Impacts of dredging in Grays Harbor

43. There are several impacts from dredging and disposal activities in Grays Harbor: in general, habitats are disrupted, turbidity and nutrient levels are increased, and dissolved oxygen is decreased. The significance of these impacts is a function of where they occur and their duration. The initial effects are observable and temporary. Other, secondary effects involving changes in the physiochemical environment are difficult to assess and may be relatively permanent if

biologic populations and hydrologic regimes are altered.

44. Dredging operations remove most fixed benthic and bottom dwelling organisms from channel troughs and bury them in disposal areas. Deposition of dredged material displaces bird and wildlife habitats; in this way 100-125 acres of tidelands in Grays Harbor are adversely affected each year (U. S. Army Engineer District, Seattle, undated). The construction of jetties and groins did create a beneficial impact by habitat diversification through the development of rocky substrate for intertidal communities (U. S. Army Engineer District, Seattle, undated). Development of marsh habitat on dredged material substrate could also be beneficial both biologically and economically by providing an alternative means of disposal that develops instead of destroys habitat. It is important to note that some areas of habitat are destroyed during the development of a marsh. This raises questions concerning the relative value of habitat types and habitat diversification, juxtaposition, interspersion, etc.

45. The problems of turbidity and low dissolved oxygen, which are associated with dredging activities and which may reduce the primary productivity of the estuary, are temporary. Although these problems occur each year, they are considered short-term and probably have no major or lasting effect on productivity.

46. In the long-term, however, the channels and disposal areas provide limited useful habitat even for the more mobile organisms. Because dredging is on an annual schedule, natural succession of plants and animals is unable to occur; with this loss of nursery and feeding areas and continuous destruction of habitat, organisms will not return. That natural succession is impossible in intertidal areas used annually for disposal sites is particularly significant since these areas provide vital nutrition, shelter, and nesting habitat for nearly every organism in Grays Harbor at some life stage. The biological values of annually used intertidal disposal sites are believed to be lost.

47. The adverse impacts of dredging and disposal activities on some of the more mobile organisms, such as crabs, is largely a disruption of nursery and feeding areas. While some of these organisms may

be killed during maintenance operations, most of the adult population is only temporarily disrupted as its members are able to move out and then return when operations cease. Less mobile organisms will be impacted by removal, smothering, and turbidity.

Studies complementary to  
the Rennie Island project

48. At the time plans were being made for the Rennie Island marsh development project, it was noted that several other studies were underway in the region that could complement the work planned at Rennie Island. One of these studies, being conducted by the HDP and mentioned earlier, was the habitat development study site at Miller Sands Island at River Mile 24 in the Columbia River. There was also a U. S. Army Engineer District, Seattle, funded study of dredging effects in the Grays Harbor area that the Washington State University Departments of Ecology, Fisheries, and Game had contracted to do. Finally, in Grays Harbor, the LFE Corporation of Richmond, California, was investigating the availability of pesticides to benthic infauna.

Description of Rennie Island

49. Rennie Island is located directly across the navigation channel from the city and port of Aberdeen (Figure 4). At the time the study was initiated, the island was about one mile long and one-third mile wide, or about 225 acres, at high tide. At low tide, an extensive mudflat extending to the south and west was exposed, and on this side of the island an accretion of marsh was evident.

50. There is a retention structure on the east end of the island that has been used by the Port Authority for disposal of dredged material. In the center of the island is an approximately 40-acre retention basin containing chemical effluents (sulfitic waste) from a process paper mill.

Habitats

51. The vegetation cover on Rennie Island ranges from trees, woody shrubs, and upland grasses to marsh vegetation. A listing of selected

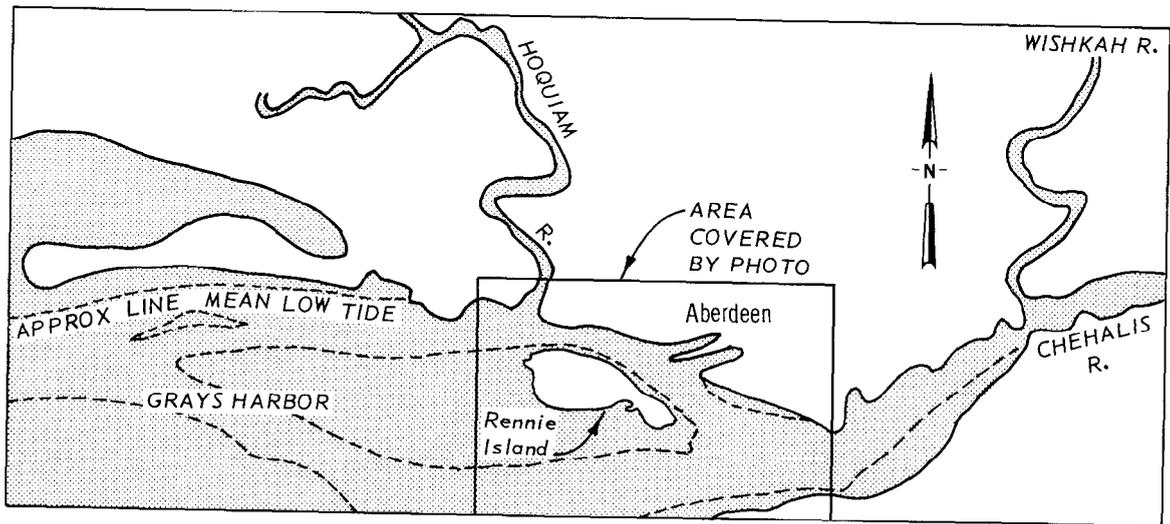
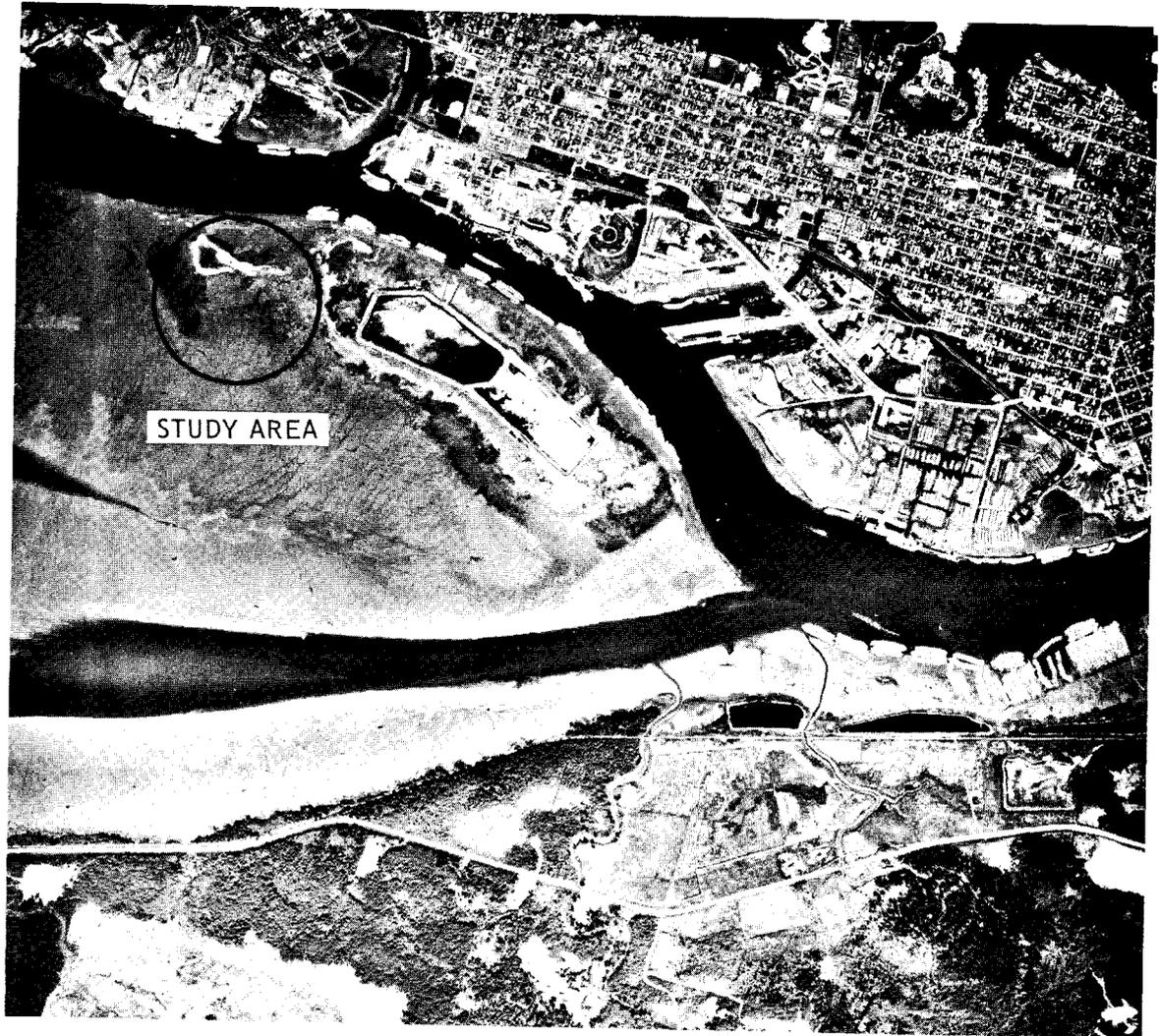


Figure 4. Rennie Island and vicinity, area of proposed marsh development

species of flora and fauna expected to occur on Rennie Island is given in Appendix B. The most common plants on Rennie Island are: American searocket (*Cakile edentula*), common velvet-grass (*Holcus lanatus*), and beard grass (*Polypogon* spp.) in the higher areas; rushes (*Juncus* spp.), seaside arrow grass (*Triglochin maritimum*), and Lyngby's sedge (*Carex lyngbyei*) in the protected areas; and brass buttons (*Cotula coronopifolia*) and three-square bulrush (*Scirpus americanus*) in the lower areas.

### Terrestrial

52. Terrestrial habitats are located west of the sulfite retention basin, on the dike of the basin, and on the sandy beach and strand area. West of the retention basin is a substantial stand of red alder (*Alnus rubra*). A freshwater pond exists within the alder stand. Occasionally extremely high storm tides reach the pond and make it brackish. The dike of the basin, the highest land on the island and a very open habitat, is covered with planted herbs, invading plants, and a few shrub and alder seedlings that are periodically cut back by the landowner. The sandy beach and strand area on the extreme western part of the island are characterized by drift logs and scattered dwarf shrubs and beach grasses. This area is surrounded by a small pioneering marsh that is separated from the main body of the island by mudflats.

### Intertidal

53. The intertidal habitats on Rennie Island include the drift area, the salt marsh, and the mudflats. At low tide various species of birds and mammals can be found in the area and at high tide fish and other marine organisms are frequent. The drift area is dominated by drift logs along storm tide lines with grass-dominated vegetation and scattered shrubs intermixed with the logs. The salt marsh, best developed on the southwest side of the island, supports a heavy cover of marsh vegetation that is inundated at high tide. The salt marsh areas on Rennie Island are dominated by Lyngby's sedge. Observations by the Seattle District, CE (unpublished data), indicate that both the salt marsh and the mudflats have a substrate characterized by sandy muds and muddy sands ranging to silty muds. The mudflats are nearly

bare of large vegetation and epifauna but occasionally patches of eelgrass occur. Some parts of the tidal flat are impacted by anchored or drifting logs settling in the mud at low tides.

54. The subtidal sediments, infauna, and vegetation are considered similar to that of the intertidal mudflats. Both the subtidal and intertidal areas are dominated by a variable estuarine water column. The water column in the Rennie Island area is often influenced by the flow of the Chehalis River. Salinities range from an average low of 5 ppt in the winter to an average high of 20 ppt in the summer. Pulp mill effluents consisting largely of sulfite waste liquors range between 5 and 50 ppm in the Rennie Island area. Sulfite waste liquors are harmful to fish and shellfish because they deplete available dissolved oxygen and increase toxicity. The critical levels of concentration are dependent on the water temperature. Water temperature near Rennie Island is highly variable with a range of 5 to 29<sup>0</sup>C. Contaminants and the variability of environmental parameters stress the pelagic and benthic flora and fauna and have reduced both diversity and abundance.

#### Aspects of the study site

55. The area selected for marsh development on Rennie Island is located west of the retention basin (Figure 5). The experimental marsh was planned to be 10 to 15 acres and to be developed by selective placement of approximately 20,000 cu yd of silty sand (SM) dredged material in a semiconfined intertidal area. The final elevation of the new marsh was to be about +8 ft above mean lower low water (mllw).

56. The new marsh area would require partial diking (Figure 5) for protection from waves and for material retention in obtaining the desired final elevation. Occasional tides of 13 ft and high wave energy would necessitate the elevation of the west dike crest to be +14 ft mllw and the dike to be fairly high-energy resistant. The other dike, to be used primarily to retain dredged material, would be about +9 ft mllw. The sandy beach and strand area to the north of the site would provide a natural dike.

57. The material for the new marsh was to be removed from the channel in the Chehalis River adjacent to Rennie Island and placed in the disposal positions shown on Figure 5.

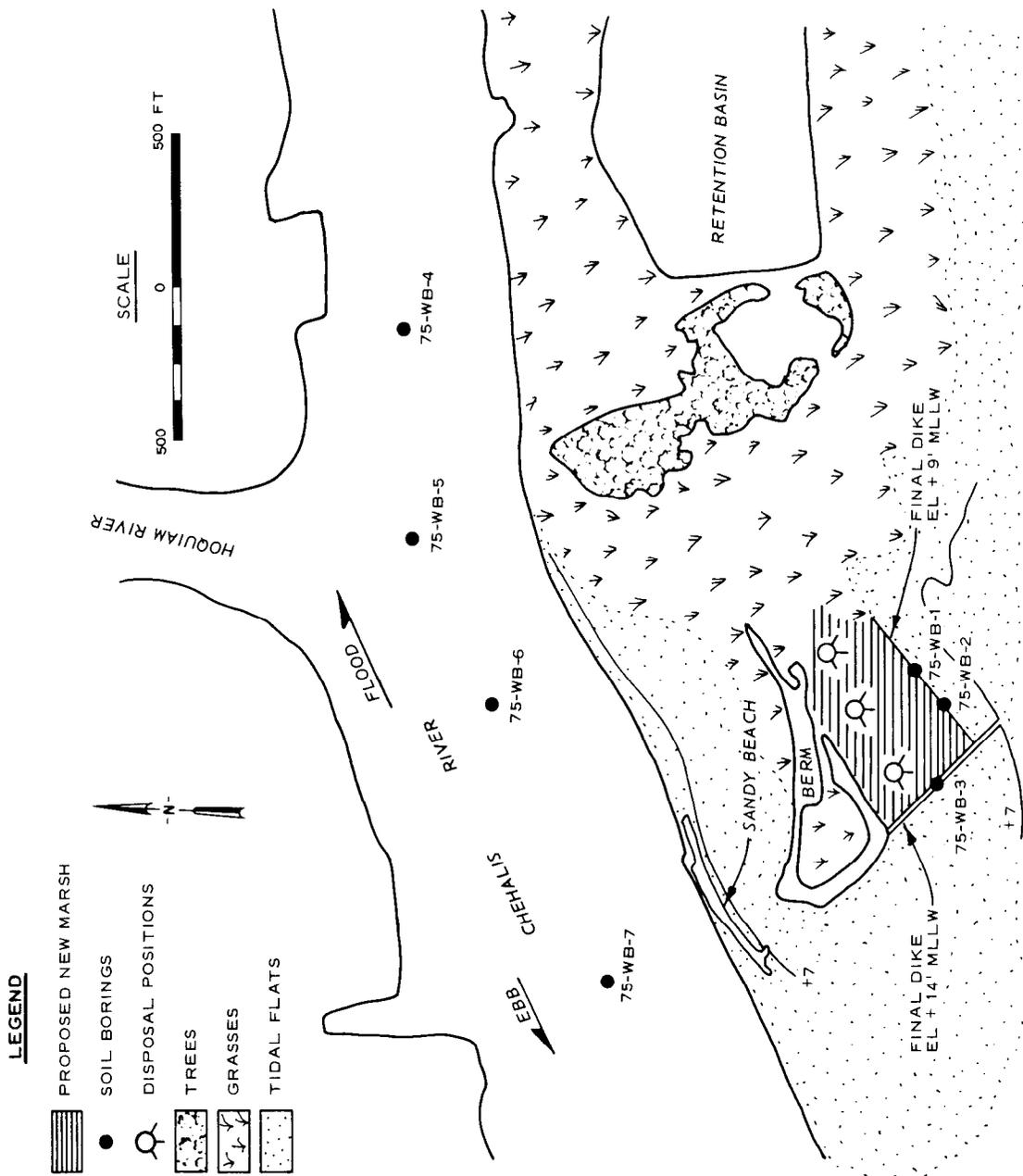


Figure 5. Preliminary plan for marsh development on Rennie Island

## PART IV: SITE ASSESSMENT

### Preliminary Survey

58. After the site was selected, an environmental inventory including literature review was begun to provide detailed information on environmental variables in the area and at the site. As part of this initial research, the Seattle District undertook an engineering survey of the proposed site on Rennie Island. The objectives of this preliminary survey were to (a) determine what information would be needed to design the marsh and appurtenant structures; (b) prescribe and implement steps to obtain that information; and (c) determine the feasibility of constructing a marsh at the proposed site.

### Approach to Inventory and Assessment Sampling Plan

59. In order to make a proper inventory and assessment, it would be necessary to collect baseline data for use in documenting the nature of natural short-term changes in the biological communities of the system resulting from dredged material disposal. Collection of biological information after dredging and disposal and site development could then be referenced to the pre-project condition to describe probable short-term (acute) effects.

60. The assessment of physical-chemical parameters, intertidal ecology, and terrestrial ecology was to include data on the biological parameters, engineering aspects, water quality, and sediment and soil chemistry at both the dredging and the disposal sites, and the nonengineering physical parameters at the disposal site.

61. A tentative sampling plan drawn up by the Fisheries Research Institute for the baseline study of Rennie Island is given in Appendix C. This three-stage plan consisted of (a) mapping topography, establishing grid systems for sampling, and mapping habitats; (b) conducting a qualitative survey and pilot survey; and (c) conducting quantitative

sampling and assessment. The qualitative survey of parameters and species in subtidal, intertidal, and terrestrial habitats was to aid in determining the optimum sampling for the quantitative survey.

62. The collected baseline data were to be placed in a storage and retrieval system then being developed for the study sites. It was also planned that several statistical parameters would be calculated routinely and stored with the data. These were to include species diversity indices (such as the Shannon-Weaver and Brillouin), density, correlation coefficients, dispersion indices, and analysis of variance.

### Engineering Investigation

63. An engineering investigation was conducted to determine the physical and engineering properties of foundation materials. This survey included field and laboratory investigations. Laboratory soils testing was performed by the Seattle District Soils Laboratory in accordance with accepted CE procedures. Classification tests included moisture content determinations, Atterberg limits tests, organic content determinations, and grain-size analyses. All soils were classified under the Unified Soil Classification System (USCS). Other laboratory tests included unconsolidated-undrained (Q) shear strength tests, consolidated-drained (R) shear strength tests, and consolidation tests.

64. Three undisturbed soil borings were made at the proposed marsh development site (Figure 5) along the proposed fill-retention dike alignment and standard penetration resistances were recorded in the sandy soils. The foundation soils were classified as inorganic silts (MH and ML).

65. Sediment samples were taken from the Chehalis River in the area to be dredged (Figure 5). Classification tests were performed on these samples and the sediments were classified as silty sand (SM).

66. Stability analyses and settlement analyses were performed by the Seattle District to determine dike stability and expected dike settlement.

## Findings of the Engineering Investigation

67. The report and findings of the engineering survey are given in full in Appendix D. Regarding substrate and structure design the survey determined:

- a. That the substrate surface should be constructed to an elevation of 8.5 to 9.5 ft mllw.
- b. That because of high tidal fluctuations, an 8- to 12-mile fetch, and 5- to 6-ft storm waves, a crest elevation of 14 ft mllw was necessary for the protective structure on the west side of the site.
- c. That a structure crest elevation of 9 ft mllw would be needed on the south side to retain the dredged material.
- d. That the sediment was classified as silty sand.
- e. That the foundation soils were classified as silts.
- f. That for acceptable safety factors, the dikes would have to be built with very flat slopes.
- g. That dikes would have to be overbuilt from 2-1/2 to 3 ft to compensate for expected settlement.

68. The survey concluded then that the soft foundation soils at Rennie Island would not successfully support an earth dike unless very flat slopes were constructed. This would cause a considerable increase in construction costs. Alternative structures were considered although they were more costly and time-consuming. Alternative sites were then considered.

## Alternative Containment Structures

69. According to the HDP time frame, dike construction was planned to begin in July 1975 and be completed in September. Dredged material substrate was to be placed on the site during winter dredging operations with disposal being completed in March 1976. The discovery that the foundation soils were extremely weak was in April 1975. Although the HDP decided to investigate alternative designs it was realized that even if another design were feasible, substrate placement would be delayed a year. In pursuing the alternatives, a \$200,000 funding

limitation on containment structure costs was imposed.

70. The Seattle District presented seven possible alternatives for a containment/protection structure at Rennie Island: (a) rubble mounds, (b) scrap tire breakwater, (c) filled tubes, (d) filled tubes with gravel fill, (e) timber bulkheads, (f) gravel dikes, and (g) gravel dikes with sandbag face (Figure 6). The estimated construction costs for these alternatives ranged from \$200,000 to \$400,000.

71. Alternatives 1 and 2, the rubble mound rock embankment and the scrap tire breakwater, were immediately eliminated from further consideration because of prohibitive costs. The two designs requiring the use of sand- or gravel-filled tubes (alternatives 3 and 4) were also quickly eliminated for several reasons. First, the Seattle District had no experience with tube structures. Second, the actual cost would be higher: the manufacturer's estimated cost was based on having suitable sand/gravel material readily available, however there was no known source of this material in the Rennie Island area. Third, it was doubtful that material dredged from the adjacent channel could be successfully used to fill the tubes.

72. The possibility of using timber bulkheads (alternative 5) was also eliminated. Actual costs for this type structure were expected to greatly exceed estimated costs because of unresolved structural/tidal hydraulics/soils engineering problems, which would have to be met by costly design features. Further, it did not seem possible to complete the timber bulkhead by the end of the summer. The most serious shortcoming of this alternative, however, was its potential aesthetic impact, which would extend beyond the planning life of the research project (removal costs were not considered in the cost estimate).

73. The remaining two alternatives (numbers 6 and 7), consisting of hydraulically constructing an embankment of sand and gravel material, were considered the most likely. It was envisioned that a bulldozer and a hydraulic dredge could build and shape the embankment to the desired final configuration. For alternative 6, a 5- to 7-ft-high embankment with a 40-ft-wide crest would be required on the west. For alternative 7, the embankment top width would be decreased by using

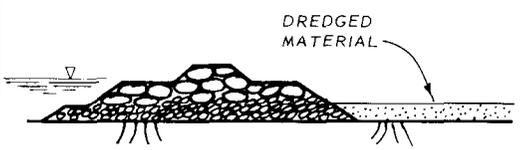
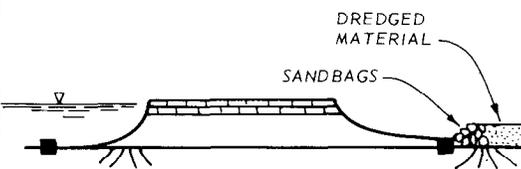
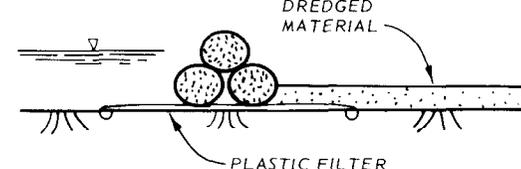
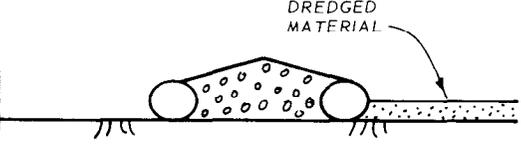
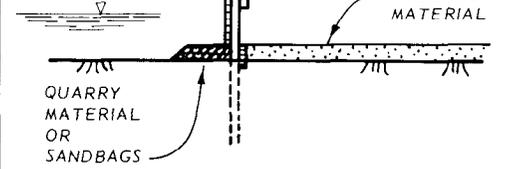
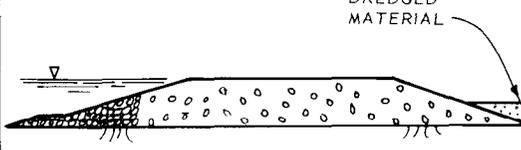
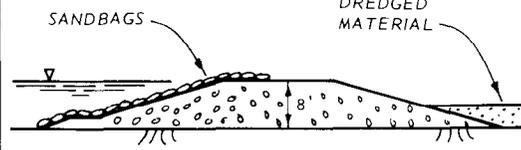
ALT	CROSS-SECTION	COST
#1 RUBBLE MOUND		\$400,000
#2 SCRAP TIRE FLOATING BREAKWATER		\$350,000
#3 FILLED TUBES		\$200,000 TO \$250,000
#4 FILLED TUBES WITH GRAVEL FILL		\$225,000 TO \$275,000
#5 TIMBER PILE		\$225,000
#6 GRAVEL DIKE (HYD FILL)		\$200,000
#7 GRAVEL DIKE WITH SANDBAG FACE		\$200,000

Figure 6. Alternative containment/protection structures considered for the Rennie Island site. (Costs were estimated in 1975.)

sandbags on the outer slope and top. Although these two techniques, or a combination of them, appeared to be a promising alternative, a suitable deposit of sand and gravel could not be found near the site (maximum allowable distance of 11,000 ft).

74. Thus, all the construction and structural alternatives proposed for the Rennie Island site were eliminated. Other sites in the area were briefly considered but none found suitable. A site requiring less energy protection measures than Rennie Island would have been of special interest.

#### Alternative Sites

75. A decision to locate a site elsewhere in Grays Harbor would be accompanied by new problems: resuming site selection procedures and determining potential difficulties specific to the new site, such as political implications and land ownership. Even if an alternative site were readily available, the relocating of the study area would present important problems in terms of the project time schedule: the physical aspects of the new site would have to be thoroughly investigated, particularly the wave energies, currents, and substrate condition.

76. Of the five sites informally proposed, four were quickly eliminated for one or more reasons including exposure to wave energy, recognized existing biological values, or problems with anticipated channel realignment.

77. The fifth site, 3.5 nautical miles west of the Rennie Island site, consisted of two large barren dredged material islands for which three years of baseline data was available. This site offered the opportunity to re-work dredged material; develop wetlands with new, contained dredged material; and compare uncontained, re-worked, and contained aspects of dredged material marsh development. The major problems here involved obtaining approval from the land owner and the fact that the long-term plans for the site ran counter to marsh development.

## Project Termination

78. Having recognized the problems at the Rennie Island site and having rejected the alternative construction designs and sites, it was decided in May 1975 to terminate plans for the project. The Fisheries Research Institute completed its work on the literature review and the preliminary study plan in July.

79. The reasons for terminating the study were:

- a. The severe foundation problems precluded the original plans for low-cost dike construction.
- b. The alternate construction plans were expected to exceed the allowable ceiling of \$200,000 and so were economically infeasible.
- c. No other site was readily available in Grays Harbor.
- d. The project time schedule would not permit a drastic change in site.
- e. Energy conditions at the site are extreme during storms.

80. Had the project continued, the problems associated with engineering aspects at Rennie Island would have jeopardized the project's short-term success (through prohibitive costs) and its long-term success (through premature or untimely destruction of marsh substrate by wave forces). The problem at Rennie Island was well stated in a report prepared, under contract to the DMRP, by the Center for the Environment and Man (Johnson and McGuinness, 1975):

"Wind driven waves are the most damaging natural erosive agents in the coastal zone and pose the greatest threat to newly created marshes... All else being equal, care should be taken to avoid sites which are exposed to large fetches in the direction of prevailing winds... The protective measures which may be required could be economically prohibitive."

While this project was terminated because of unfavorable conditions at Rennie Island, there are sites within Grays Harbor where marsh habitat development is feasible.

## PART V: SUMMARY AND CONCLUSION

### Summary

81. In an effort to obtain study sites for habitat development in a variety of coastal environments, including the Pacific Northwest, the DMRP and the Seattle District selected an apparently suitable site in Grays Harbor, Washington. The site, on Rennie Island near Aberdeen, Washington, was to provide an opportunity to study a 10- to 15-acre development of salt marsh established by man on organic sandy silt dredged material in a high-energy environment. The marsh development was to take place in association with an authorized and coordinated maintenance dredging project and with the assistance of the Seattle District.

82. With the site-selection criteria satisfied and the project schedule set, baseline work on the site began. The Seattle District undertook an engineering survey of foundation and surface materials conditions and began planning the design for dike construction and substrate placement. The Fisheries Research Institute at the University of Washington initiated a multifaceted study in order to assess the suitability of the site for marsh development. Early on in the engineering survey it became apparent that the extremely weak foundation at the site would greatly complicate the design of the retention structure that was already specialized by its need to retain and protect dredged material in a high-tidal-range environment.

83. Various containment structures using a variety of materials were investigated as alternate possibilities to the original design. Alternative site locations in Grays Harbor were also briefly considered. However, for reasons of expense, availability of construction materials, and physical environmental constraints, none of the alternative structures was deemed feasible. In addition, no other satisfactory site was readily available so the DMRP terminated the marsh development project in Grays Harbor in May 1975.

## Conclusion

84. Although the Rennie Island project was aborted, the work done there was not a total loss. Besides the site information obtained, lessons were learned that are applicable to practical, economic, and operational aspects of site selection and project planning and design at other field sites. The Rennie Island study should be of interest to others concerned with marsh development as a dredged material disposal alternative. This project was terminated because of unfavorable conditions at Rennie Island; however, there are sites within Grays Harbor where marsh habitat development is feasible.

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## APPENDIX D: ENGINEERING CONSIDERATIONS

### Introduction

1. During the planning phase of the Rennie Island Marsh Development Project a number of questions had to be answered concerning foundation conditions at the site, structures to be used for dredged material retention and marsh protection, characteristics of sediments to be dredged, size and shape of structures, and economic and engineering feasibility of construction. The Seattle District performed engineering investigations to provide answers to these questions.

### Field Investigations

2. Field investigations at the Rennie Island site and in the Chehalis River were conducted to characterize the foundation conditions at the proposed marsh development site and to characterize the sediment to be used as marsh substrate. The investigations consisted of soil borings to obtain samples for laboratory testing.

3. Three wash borings were made on Rennie Island along the proposed confining structure alignment. The approximate locations of these borings are shown in Figure 5 of the main text. These three borings extended from about elevation +7.5 ft mllw to a maximum of -41.5 ft mllw. Three-in. undisturbed tube samples were taken at several selected depths in each boring and standard penetration resistances were recorded with a 1-3/8-in.-I.D., 2-in.-O.D. split spoon using a 140-lb hammer with a 30-in. drop at several depths in each boring. The penetration resistances were recorded as the number of blows (N) required to drive the hammer one foot into the foundation soils.

4. Four wash borings were made in the Chehalis River to obtain samples of the sediment to be dredged. The maximum depth of these borings was -63.5 ft mllw. Three-in. undisturbed tube samples were taken at selected depths and standard penetration resistances were recorded. Surface samples were taken of the sediment near the center of the channel at stations 204+00 and 217+00.

## Laboratory Testing

5. Laboratory soil and sediment testing was performed by the Seattle District Soils Laboratory in accordance with accepted CE procedures. All undisturbed samples were classified under the Unified Soil Classification System (USCS), and water content determinations were made for all fine-grained samples. Atterberg Limits were performed on selected samples of fine-grained material. Grain-size analyses were performed on portions of the undisturbed samples. Shear strength tests consisted of unconsolidated-undrained (Q) and consolidated-drained (R) triaxial tests on selected samples. Consolidation tests were performed on a total of four samples selected from borings 75-WB-1 and 75-WB-3. Results of the tests are summarized in Tables D1 and D2.

## Foundation Conditions

6. The results of the field and laboratory investigations on foundation soils at Rennie Island indicated that these soils would be poor foundations for the retaining and protective structures required for marsh development. These soils consisted of weak silts classified as MH and ML. Shear strengths were very low for the wet silts.

## Sediment Characterization

7. The sediments sampled from the Chehalis River were classified as silty sand (SM). Varying amounts of wood chips and bark and other organic debris were found in the river sediments. These coarse-grained sediments would cause no problems in making predictions of final substrate elevations for the marsh. These soils would stabilize quickly when placed and would present no significant settlement or dewatering problems. However, the foundation on which they would be placed would result in settlement of the proposed marsh substrate.

8. Grain-size analyses indicated that sediment gradations ranged from 80 percent passing the No. 40 sieve and 16 percent passing the

Table D1

Summary of Atterberg Limits and Shear Strength Data

Boring No.	Sample No.	Classification	Liquid Limit LL	Plastic Limit PL	Plasticity Index PI	Shear Strength			
						Q	C	$\phi$ deg.	R
75-WB-1	1A	MH	54	50	14	0.06	-	-	-
	1C	ML	47	35	12	-	-	-	-
	1E	ML	48	36	12	-	-	-	-
75-WB-3	3A	MH	55	41	14	0.01	-	-	-
	3C	ML	44	30	6	-	-	-	-
	3E	ML	36	29	7	-	22	0.08	-
	3H	ML	39	30	9	-	-	-	-

Table D2

Summary of Consolidation Data

Boring No.	Sample No.	Classification	Compression Index $C_c$	Initial Void Ratio $e_o$	Natural Water Content $W_o$ (%)	Dry Density $\frac{\text{lb}}{\text{cu ft}}$	Specific Gravity $G_s$
75-WB-1	1C	ML	0.27	1.499	56.3	67.2	2.69
75-WB-3	3A	MH	0.30	1.696	64.9	61.3	2.65
75-WB-3	3E	ML	0.38	1.447	57.6	65.8	2.58
75-WB-3	3H	ML	0.49	1.638	61.5	63.9	2.70

No. 200 sieve ( $D_{60} = 0.28$  mm;  $D_{50} = 0.24$  mm; and  $D_{10} = 0.03$  mm) to 98 percent passing the No. 40 sieve and 77 percent passing the No. 200 sieve ( $D_{60} = 0.032$  mm;  $D_{50} = 0.02$  mm; and  $D_{10} = 0.003$  mm).

### Structure Alignment and Height

9. The alignment of the proposed structure is shown in Figure 5. The Rennie Island site is subjected to high tidal fluctuations and an 8- to 12-mile fetch aligned toward the prevailing storm-wind direction. About twice annually Grays Harbor experiences storm-generated waves of 5 to 6 ft. Based on these conditions it was decided that the structure on the west side of the site should have a crest elevation of +14 ft mllw. Since the south side would not be exposed to these same conditions, it was decided that a crest elevation of +9 ft mllw would be sufficient for that structure.

### Structure Selection

10. The retaining structure for protection during construction and dredged material retention would have to be about 3 ft higher than the final crest elevations indicated in the preceding paragraph. A final marsh substrate elevation of +9 ft mllw was planned.

11. Stability and settlement analyses were performed by the Seattle District to determine the stability of a proposed earth-filled dike to estimate foundation settlement caused by placement of the dike. These analyses indicated that because of the poor foundation conditions, the earth-filled dike would require extremely flat side slopes for stability and that foundation settlements of 2.5 to 3 ft might be expected. The Seattle District concluded from these analyses that the foundation soils would not support an earth-filled dike unless the dike was constructed in stages with time allowed between stages for consolidation and strength increases to occur. For this reason construction of an earth-filled dike would be uneconomical, and it could not be built within the construction schedule imposed by the DMRP.

## Other Structures Evaluated

12. A careful evaluation of possible alternatives for providing a protective structure was made in light of the dilemma presented in the foregoing paragraph. The alternatives are briefly summarized in the following:

13. Rock embankment. Two-stage construction required due to soft foundation soils. Estimated cost: \$400K. Although adequate supply of fractured rock embankment fill was available, required construction time would not be compatible with DMRP time table, due to required staged construction. This alternative was not considered feasible due to excessive cost and unsatisfactory construction schedule.

14. Timber pile bulkhead. Although cost was initially estimated at \$225K, unresolved structural and tidal hydraulics engineering problems were expected to increase more refined cost estimates to a prohibitive level of \$250K or above. Further, the requirements that the bulkhead be constructed in summer would have exerted additional constraints on project planning, design, and construction scheduling. Perhaps the most serious shortcoming of this alternative, however, was its potential aesthetic impact, which would have extended beyond the planned life of the research project. For all of these reasons, this alternative was given no further consideration.

15. Hydraulically-placed embankment. Cost of implementing this alternative was estimated at \$200K, assuming a suitable sand/gravel source could be located adjacent to the navigation channel, and assuming a dredging contractor would construct the embankment in conjunction with channel dredging (i.e., no separate contractor mobilization cost). It was planned that a bulldozer, operating in conjunction with the hydraulic dredge, would shape the embankment to the desired final configuration. Unfortunately, a search did not locate a suitable sand/gravel deposit near the proposed marsh site.

16. Filled tubes. Two other alternatives required the use of large flexible sand- or gravel-filled tubes. Although near-favorable cost estimates were provided by manufacturer's marketing representatives

(\$220-275K), they were based on availability of sand/gravel materials in close proximity to the site.

17. Scrap tire floating breakwater. The costs were too high for this alternative. Preliminary cost estimates exceeded \$350,000.

18. Gravel dike with sandbag face. This alternative is simply an aberation of paragraph 15. Although slightly more favorable in cost, the lack of suitable source of sand and gravel precluded further consideration of this alternative.

19. Site change. A site change was considered but no suitable site could be found within the established time frame of the DMRP and other schedule restrictions.

### Conclusions

20. Based on the field and laboratory investigations and subsequent evaluation of these investigations, the following conclusions are warranted:

- a. The foundation conditions on Rennie Island are very poor.
- b. Stage construction required for an earth-filled dike would not permit its construction within the time frame scheduled by the DMRP.
- c. Other type structures were not economically feasible.

21. It was concluded that because of the poor foundation conditions on Rennie Island and the lack of suitable construction materials near the site, marsh development at this site would be prohibitively expensive. Rennie Island was eliminated from further consideration as a marsh development site during the spring of 1975.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Vincent, Mary K

Habitat development field investigations, Rennie Island marsh development site, Grays Harbor, Washington; summary report / by Mary K. Vincent. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

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Appendices A-C on microfiche in pocket.

Includes bibliographies.

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